APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

METHOD AND SYSTEM FOR RECEIVER-CHARACTERIZED POWER SETTING IN A CELLULAR COMMUNICATION SYSTEM

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[0001] This application claims priority under 35 U.S.C. § 120 to U.S. Provisional Application No. 60/265,613, filed February 2, 2001, the entire contents of which are herein expressly incorporated by reference.

BACKGROUND

Field of the Invention

[0002] The present invention relates generally to wireless communication. More specifically, the present invention relates to a method and system for receiver-characterized power setting in a cellular communication system.

Background Information

[0003] The cellular telephony industry is presently experiencing extreme subscriber growth. The number of cellular telephony users is increasing at a rate comparable or higher to that of Internet usage and web browsing. Even though the most intense development and evolution of cellular communication today concerns the merger of Internet and mobile telephony, i.e., mobile access to the Internet, it is still envisioned that voice services will be a dominant application for many years to come. As the number of cellular subscribers increase, improvements for voice services become increasingly important for all manufacturers and mobile operators. Consequently, solutions are needed for

boosting the radio network capacity and for more efficiently utilizing the limited available spectrum an operator is allowed to use.

[0004] In cellular communication systems, reuse patterns are deployed in such a manner that one can reuse the same frequencies in different cells. Systems are usually planned such that a number of cells share a number of available channels. For example, in a 4/12 frequency reuse, there are 12 different cells that share a set of frequencies. Within these 12 cells, no frequency is used in more than one cell simultaneously. (The number 4 in "4/12" denotes the number of base station sites involved in the 12 reuse. The 4/12 notation thus indicates that a base station site serves 3 cells.) These 12 cells form what is referred to as a "cluster." Clusters are then repeated to provide coverage in a certain area. Similarly, in a 1/3 reuse there are 3 different cells that share a set of frequencies. Within these 3 cells, no frequency is used in more than one cell simultaneously.

[0005] Thus, the lower the reuse (e.g., 4/12), the better the carrier-to-interference ratio for an exemplary condition. The carrier-to-interference (C/I) ratio is a measure of the relation between the wanted signal and the sum of all of the unwanted signals. For higher reuse patterns (e.g., 1/3 or 1/1), the C/I ratio is lower, since the repetition distance between two base stations transmitting on the same frequency is smaller. An example of a 1/3 reuse is illustrated in FIG. 1.

[0006] FIG. 1 illustrates an exemplary cellular pattern according to a Global System for Mobile Communications (GSM) radio network 100. GSM uses narrowband time-division multiple access (TDMA) in which frequencies are separated by a 200 kHz carrier spacing. Frequencies are typically planned for use in a certain area, e.g., a cell, and then reused in another area, e.g., another cell, that is remote from the first area. The planning of frequencies aims to introduce sufficient re-use distance such that communication on, for example, Fl in one area does not interfere with communication on Fl in another area. In FIG. 1, a theoretical 1/3 reuse is illustrated. The 1/3 reuse indicates that there are 3 different frequency groups that are repeated throughout the coverage area. Frequencies Fl, F2 and F3 are evenly distributed throughout a coverage area, each frequency serving a sub-area, or cell. For ease of explanation and not limitation, the description of FIG. 1 refers to each cell being assigned a frequency. However, it will be recognized that more than one frequency can be assigned per cell. In such a case, F1, F2, and F3 each represent a plurality of frequencies that would be repeated in accordance with the particular reuse pattern being implemented. Further, the notation Fl can also correspond to a certain set of frequencies between which allocations "hop" at certain intervals. This is referred to as a frequency hopping system or frequency hopping allocations.

[0007] The frequencies can be planned in any reuse pattern, depending on how much spectrum is available and how much interference can be allowed in the network. The reuse pattern illustrated in FIG. 1 is theoretical. In a real network, cells are non-homogeneous and the reuse pattern can vary due to, for example, variations in topology and geographical conditions. In FIG. 1, a mobile station (MS) 110 is located in a cell served by base station 115 and communicates with the base station 115 using frequency (group) Fl. Corresponding to another base station 105, a similar arrangement is found. If the mobile station 110 moves, for example, into a cell served by base station 105, mobile station 110 will start communicating with base station 105 instead, using the frequency (group) assigned for the specific cell to which mobile station 110 has moved.

[0008] In the effort to improve capacity, emphasis has been placed on two types of scenarios for which a system can be limited — the blocking limited scenario and the interference limited scenario. In the blocking limited scenario, the capacity is limited, because there are no channels available to allocate to an additional user. For example, in GSM, where communication occurs on channels that are realized on timeslots (or multiples or parts of a timeslot), a new user cannot be allocated any timeslot resources when the timeslot resources are all occupied. It is possible to overcome this limitation by planning the system with a higher reuse pattern, e.g., repeating the frequencies (timeslots) more often and

thereby provide for a higher channel availability in each cell. However, a higher interference level is introduced with the higher reuse. As a result, the system is affected by the second type of limitation — the interference limited scenario.

[0009] In the interference limited scenario, channels are available, but it is not possible to allocate more users because the C/I ratio will become too low. Consequently, services for one or several of the users cannot be offered with sufficient quality. Interference limited scenarios will work satisfactorily if operators limit the load of the available channels to less than 100 percent, and typically much less. Thus, only a fraction of the number of physical channels allocated in a cell (e.g., a timeslot) may be utilized so as not to introduce more interference than can be allowed in providing services with a sufficient quality level. Generally, the trend in the cellular industry is to move towards interference limited systems to maximize capacity.

[0010] Currently, the TDMA-based GSM cellular communication system utilizes a voice codec (coder/decoder) specially designed for the type of radio transmissions that are used in the system. The voice codec presently used is often referred to as GSM Enhanced Full Rate (EFR) codec and is the successor to the "ordinary" GSM Full Rate (FR) voice codec. The GSM EFR codec is designed to perform optimally at the symbol rates available with the GSM radio frequency carriers. With the GSM EFR, a specific binary representation of the speech in

terms of more or less significant symbols is used, as well as a specific channel coding for correcting errors inflicted by varying radio conditions. The quality with the GSM EFR codec is improved over that of the earlier generation of voice codecs for GSM (the GSM FR codec) and the EFR codec has proved to be a great success in the mobile communications industry.

[0011] The evolution of voice codecs has, however, not ended with the EFR codec. Rather, improvements in speech coding over varying radio channels have been the subject of intense research and new voice codecs have evolved. The generation of voice codecs following the EFR codecs for GSM is generally referred to as Adaptive Multi-Rate (AMR) codecs.

[0012] The AMR codec family differs from all previous voice codec generations used in GSM, because the AMR is not just one codec. Rather, the AMR codec is a set of different speech codecs. With the AMR codec, the speech coding and channel coding is optimized based upon the instantaneous quality of the radio link. In this respect, the AMR voice codec includes a set of different codec modes that are selected at different instants. The codec mode selected is based upon, for example, reported measurements of the radio conditions or of the perceived quality. The procedure for selecting the codec mode that is most suited for a certain radio channel condition is called "link adaptation." The AMR codec is more thoroughly characterized in the GSM specification document ETSI TR 101

714 specification GSM 06.75, version 7.2.0, April 2000, which is hereby incorporated by reference in its entirety.

[0013] While the EFR codec provides adequate voice quality at a certain radio channel condition, usually characterized or quantized in a C/I ratio, the AMR codec can provide the same voice quality at a much lower C/I ratio. Thus, the AMR codec is less sensitive to interference. For any given C/I value, the AMR codec provides equal or better voice quality than the GSM EFR codec.

[0014] For the EFR codec, the amount of speech coding output symbols (i.e., the binary representation of the speech) is always the same and the amount of channel protection (i.e., channel coding) is always the same. With the AMR codec, however, it is possible to select different codec modes dependent upon the quality of the radio channel. Different codec modes have different amounts of channel coding and different amounts of symbols representing the speech (i.e., voice codec output). For example, for a channel condition with a low quality, i.e., with a large amount of interference, the AMR codec can select a codec mode where the speech is represented by only a few symbols and where the channel protection (channel coding) is stronger (i.e., the major part of the transmission may be channel coding bits). For a channel condition with a high quality, i.e., with a small amount of interference, the AMR codec can select a codec mode where the speech is represented by a larger amount of symbols and where less

transmission resources are spent on channel protection (channel coding). In this way, the AMR codec can better adapt to the instantaneous channel quality and better follow, for example, the varying conditions in a cellular communication system. This adaptation to the channel quality allows the AMR codec to provide a better speech quality in a wider range of channel conditions. Thus, the degradations sometimes experienced with the EFR codec can be better handled with the AMR codec.

[0015] In terms of increasing system capacity, the AMR technique can be viewed as a feature that provides the same quality as the GSM EFR codec, but at a lower C/I level. In an interference limited system, this can be translated into a higher capacity. However, the AMR codec is not implemented in all mobiles in use in a cellular system. For example, all mobiles that are in use today lack the AMR functionality.

[0016] A mobile station with the AMR codec will typically have a more robust radio connection with a base station. A lower Frame Erasure Rate (FER) or Block Error Rate (BLER) will be experienced for any given average C/I. In other words, a lower C/I can be tolerated for a given FER or BLER target. The users with a new mobile station that includes the AMR codec will experience a higher quality, but the interference contribution from a new mobile station will be the same as for an old mobile station, as long as the transmission powers are the

same. If AMR and EFR connections are operated in a common frequency band, it is thus not possible to directly translate the quality increase into, e.g., any general capacity increase since older (EFR) mobile stations will not experience increased quality. Increasing the number of users will, therefore, result in a negative impact on old mobile stations.

[0017] One possible solution can be to divide the available spectrum into a spectrum for old mobile stations and a spectrum for new mobile stations. It would then be possible to increase the capacity in the part of the spectrum serving the new mobile stations that have the AMR codec functionality. This is, however, not desirable, because it will require a re-engineering of spectrum when the frequency band split is performed. There will also be a loss of trunking efficiency, since both new and old mobile stations will have to share fewer frequencies than without a frequency split, which will increase the blocking rate. In addition, if frequency hopping were implemented in a system where the available spectrum is split, there will be a loss in the frequency and interference diversity, since the gain from frequency hopping is highly dependent on the number of frequencies used for hopping. Furthermore, the capacity gain will only be for the new mobile stations, as it is not possible to increase the capacity in the part of the spectrum associated with the old mobile stations.

[0018] Another consideration with regards to the AMR codec and the high voice quality at low C/I ratios is that even though the speech channels have experienced a positive evolution in increased robustness, similar improvements have not been designed for the control channels associated with speech communication. Thus, for speech communication utilizing the AMR codec, a user may have excellent voice quality, but may still be dropped or loose the call due to control signaling failures. The associated control signaling robustness is designed to work well with the channel conditions acceptable for the GSM EFR codec, but the significantly lower C/I ratios that the AMR can handle are too poor for the associated control channels.

[0019] It would be desirable to introduce mobile stations with the AMR codec functionality into a cellular system such that capacity gains can be realized in a spectrum shared with mobile stations lacking the AMR codec functionality. In addition, it would be desirable to find a solution that addresses the robustness of the associated control channels and that decreases the risk that a call may be lost or dropped due to control signaling failure.

SUMMARY OF THE INVENTION

[0020] A method and system are disclosed for receiver-characterized power setting in a cellular communication system. In accordance with exemplary embodiments of the present invention, a first transmission power is set for a first

connection with a first type of mobile station. The first connection targets a first radio channel quality. A second transmission power is set for a second connection with a second type of mobile station. The second connection targets a second radio channel quality. The first type of mobile station uses a first type of speech unit that is less robust to poor radio channel quality than a second type of speech unit used by the second type of mobile station. The first and second transmission powers are set according to at least a type of speech unit used by the first and second types of mobile stations, respectively, when transmitting speech.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0021] Other objects and advantages of the present invention will become apparent to those skilled in the art upon reading the following detailed description of preferred embodiments, in conjunction with the accompanying drawings, wherein like reference numerals have been used to designate like elements, and wherein:

[0022] FIG. 1 illustrates an exemplary 1/3 cellular reuse pattern.

[0023] FIG. 2 illustrates a reference model of a GSM/GPRS cellular communication system.

[0024] FIGS. 3A and 3B illustrate the steps for receiver-characterized power setting in a cellular communication system in accordance with exemplary embodiments of the present invention.

[0025] FIG. 4 illustrates a voice codec device in accordance with an exemplary embodiment of the present invention.

[0026] FIG. 5 illustrates a system for receiver-characterized power setting in a cellular communication system in accordance with an exemplary embodiment of the present invention.

[0027] FIG. 6 illustrates a power control device in accordance with an exemplary embodiment of the present invention.

[0028] FIG. 7 illustrates the different radio quality targets for AMR voice codec quality, AMR voice codec associated control signaling quality, EFR voice codec quality, and EFR voice codec associated control signaling quality in accordance with an exemplary embodiment of the present invention.

[0029] FIG. 8 illustrates a histogram of a power distribution for EFR and AMR mobile stations in accordance with an exemplary embodiment of the present invention.

[0030] FIG. 9 illustrates an exemplary radio channel quality mapping in accordance with exemplary embodiments of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] FIG. 2 illustrates a reference model of a GSM/GPRS cellular communication system. As shown in FIG. 2, a mobile telecommunications system 200 includes a circuit switched part and a packet switched part. According to

exemplary embodiments, the circuit switched part is a Global System for Mobile Communications (GSM) circuit switched communication system and the packet switched part is a General Packet Radio Service (GPRS) based packet switched communication system. Generally, the circuit-switched network is primarily used for voice applications. In accordance with third generation mobile telecommunications evolution, however, the circuit-switched network can also support data communications, and the packet-switched network can also support voice communications.

[0032] The circuit-switched network includes a number of nodes, e.g., Mobile Switching Center/Visitor Location Registers (MSC/VLRs) 216. For purposes of simplifying the illustration, only one MSC/VLR 216 is shown. Each MSC/VLR 216 serves a particular geographic region and is used for controlling communications in the served region and for routing communications to other MSC/VLRs (not illustrated). The VLR portion of the MSC/VLR 216 stores subscriber information relating to mobile stations 210 that are currently located in the served region. Although mobile station 210 is illustrated as a computer, any mobile communication device can be used, e.g., voice terminals. The circuit-switched network further includes at least one gateway mobile switching center (GMSC) 220 that serves to connect the circuit-switched network with external networks, such as, for example, a public switched telephone network (PSTN) 228.

[0033] The packet-switched network includes at least one serving GPRS support nodes (SGSN) 218 that is used for routing and controlling packet data communications, and a backbone IP network 222. A gateway GPRS support node (GGSN) 224 connects the packet-switched network with an external IP network 230 or other external data networks.

[0034] The radio network includes a plurality of cells. Each cell in the mobile telecommunications system 200 is served by a base station 212 that communicates with mobile stations 210 in the cell via an air interface 211. A radio base station controller (BSC) 214 controls a plurality of base stations 212. For circuit-switched communications, signals are routed from the MSC/VLR 216 to the BSC 214 via an A-interface 215. Signals can be further routed down to the base station 212 for the cell in which the target mobile station 210 is currently located, and over the air interface 211 to the mobile station 210. For packet data transmissions, however, signals are routed from the SGSN 218 to the BSC 214 via a Gb-interface 219. Signals can be further routed down to the base station 212 for the cell in which the target mobile station 210 is currently located, and over the air interface 211 to the mobile station 210.

[0035] Each mobile station 210 is associated with a home location register (HLR) 226. The HLR 226 stores subscriber data for the mobile station 210 that is used in connection with circuit-switched communications and can be accessed by

the MSC/VLRs 216 to retrieve subscriber data relating to circuit-switched services. Each mobile station 210 is also associated with a GPRS register 227. The GPRS register 227 stores subscriber data for the mobile station 210 that is used in connection with packet-switched communications and can be accessed by the SGSNs 218 to retrieve subscriber data relating to packet-switched services.

[0036] Voice and data communications can be sent via the air interface 211 using one or more time slots. In many cases, each time slot is allocated to a single mobile station 210 for use in receiving communications from, and transmitting communications to, the base station 212.

[0037] In mobile telecommunications system 200, a voice codec can be located in the base station 212, in the BSC 214, or farther up in the network. Furthermore, the base station 212 and the mobile station 210 can include features for handling frequency hopping allocations. A frequency hopping allocation refers to a resource allocation for a certain connection that includes several frequencies in which the connection, in a pseudo-randomized or controlled manner, switches between different frequencies at a certain rate. There are several advantages to using frequency hopping. One advantage is that it is possible to achieve a frequency diversity in a connection. For example, if a mobile station is geographically positioned such that a certain frequency shows low performance due to frequency-related multi-path fading, this situation will change and generally

improve at the speed of the frequency hopping rate. Another advantage is that if a certain allocation is experiencing a very strong interfering signal, this situation will also change with the frequency hopping rate as long as the interferer does not frequency hop synchronously. Thus, the frequency hopping mechanism can be viewed as a distributor of interference- and frequency-related fading, such that no single connection continuously experiences a bad radio channel quality.

[0038] FIGS. 3A and 3B illustrate the steps for controlling transmission powers in a cellular communication system. In FIG. 3A, in step 300, a first transmission power is set for a first connection with a first type of mobile station. The first connection targets a first radio channel quality. In step 305, a second transmission power is set for a second connection with a second type of mobile station. The second connection targets a second radio channel quality. The first type of mobile station uses a first type of speech unit that is less robust to poor radio channel quality than a second type of speech unit used by the second type of mobile station. The first and second transmission powers are set according to at least the type of speech unit used by the first and second types of mobile stations, respectively, when transmitting speech. According to exemplary embodiments of the present invention, the first type of speech unit used by the first type of mobile station is an Enhanced Full Rate (EFR) voice codec unit, and the second type of speech unit used by the second type of mobile station is an Adaptive Multi-Rate

(AMR) voice codec unit. The first and second types of mobile stations can have, for example, different receiver characteristics.

[0039] The mobile telecommunications system 200 can support voice communication using a number of different voice codecs. FIG. 4 illustrates a voice codec device according to an exemplary embodiment of the present invention. In FIG. 4, a voice codec device 400 can enable either or both GSM EFR speech communication and GSM AMR speech communication. As shown in FIG. 4, the voice codec device 400 includes both an AMR voice codec 402 and an EFR voice codec 404. However, skilled artisans will recognize that voice codec device 400 can alternatively include either AMR voice codec 402 or EFR voice codec 404. For a certain connection, the use of either the AMR voice codec 402 or the EFR voice codec 404 is dependent on the capabilities of the mobile station device involved in the connection.

[0040] According to exemplary embodiments, the first and second types of mobile stations share substantially the same frequency band for the first and second connections. In addition, frequency hopping allocations can be used for the first and second connections. Applying frequency hopping to the connections can lead to a reduced interference for all users within the spectrum used. The frequency hopping can distribute the interference contributions from all users evenly over all carriers used in an allocation, which can lead to a capacity gain for

all types of mobiles, i.e., independent of AMR codec capability. By using a combination of a shared frequency band, frequency hopping, and power control, a radio channel quality gain can be achieved for both EFR-equipped and AMR-equipped mobile stations, that can be used for increasing the network capacity for both types of mobile stations. Furthermore, there will be no changes necessary to the radio network in terms of dividing the spectrum into one part used for connections with AMR mobile stations and another part used for connections with EFR mobile stations. The trunking is also maintained, since no spectrum division is necessary.

[0041] The first and second radio channel qualities can correspond to, for example, a desired carrier-to-interference (C/I) ratio or any other form of radio channel quality measure. According to exemplary embodiments, the second radio channel quality is substantially lower than the first radio channel quality. In such an embodiment, two different radio quality targets are used for the power control feature of the present invention — a high radio channel quality target for mobile stations equipped with the EFR voice codec (i.e., the "old" mobile stations) and a lower radio channel quality target for mobile stations equipped with the AMR voice codec (i.e., the "new" mobile stations).

[0042] According to an alternate exemplary embodiment, the radio channel quality used for "old" mobile stations can be used for both "old" and "new"

mobile stations. In such an alternate embodiment, two different radio channel quality mappings are needed. The second radio channel quality is mapped from a corresponding first radio channel quality. For example, FIG. 9 illustrates an exemplary radio channel quality mapping in accordance with exemplary embodiments of the present invention. As shown in FIG. 9, a mapping of C/I to speech quality can be used, although skilled artisans will recognize that any quality measure can be used for the mapping, for example, bit error rate (BER) to speech quality, and that the mapping illustrated in FIG. 9 is for purposes of illustration and not limitation. According to FIG. 9, a certain level of speech quality DQ 906 is desired. To fulfill speech quality level DQ 906 for an AMR mobile station (i.e., the second type of mobile station, represented as curve 902), the power control feature according to exemplary embodiments of the present invention strives for a C/I of, for example, 4 dB. However, to fulfill the same speech quality level DQ 906 for an EFR mobile station (i.e., the first type of mobile station, represented as curve 904), the power control feature strives for a C/I of, for example, 10 dB. The user-perceived quality of the second radio channel quality for the second type of mobile station corresponds to substantially the same user-perceived quality of the first radio channel quality for the first type of mobile station.

[0043] Thus, the radio quality experienced by an AMR mobile station is translated to a virtual radio channel quality for an EFR mobile station, and the radio channel quality target for the EFR mobile stations can remain unchanged. Consequently, as illustrated in FIG. 9, for, for example, the C/I estimated for an AMR mobile station, the power control feature can use, for example, a higher value in order to mimic an EFR mobile station in the radio channel quality filtering process. The power control target for the EFR mobile stations can still be used and no new radio channel quality target is needed, since the AMR mobile stations are given a radio channel quality corresponding to that targeted by the EFR mobile stations. Thus, no new radio channel quality parameter is required in mobile station product implementations.

[0044] In addition to different radio quality targets, two power spans (i.e., the difference between maximum and minimum allowed power) can be used for the AMR- and EFR-equipped mobile stations. The power control feature according to exemplary embodiments of the present invention can reduce the power for an AMR mobile station below the minimum power for an EFR mobile station. In addition, AMR mobile stations can use a lower power than the EFR mobile stations to exploit full interference reduction, such as when the radio channel quality gain with the AMR mobile stations is large, e.g., 6 dB for AMR mobile stations compared to EFR mobile stations. In such an example, the average power

for the AMR mobile stations should be approximately 6 dB smaller than the corresponding value for EFR mobile stations. Thus, according to exemplary embodiments, the minimum power used for the second connection with the second type of mobile station (the AMR mobile station) is lower than the minimum power used for the first connection with the first type of mobile station (the EFR mobile station).

[0045] According to an alternate exemplary embodiment of the present invention, a power control mechanism for regulating output power in the downlink direction (from the base station to the mobile station) is at least partially based on the type of voice codec used for the connection when transmitting speech. If a downlink voice communication utilizes an AMR codec, the power control target for that connection is set to a substantially lower value than a downlink voice communication where an EFR codec is utilized. The difference in power control target can be determined by, for example, a user perceived speech quality target. In the particular case of the AMR and EFR codecs, the quality that is achieved at, for example, a certain C/I with the EFR codec is achieved at a lower C/I with the AMR codec. The power control target for the AMR codec can be decreased by a substantially corresponding amount for the AMR codec relative to the EFR codec power control target. In this context, the power control target is actually a

translation of a radio channel quality, for example, in terms of C/I. The C/I ratio is, however, directly affected by the power control target in any given case.

[0046] Together with frequency hopping, the power control strategy according to exemplary embodiments of the present invention can allow for the addition of more users to a cellular communication system, since the contribution of interference per user is decreased with the down-regulated AMR codec mobile stations. With the frequency hopping allocations, the interference gain is distributed along the complete spectrum. If several types of mobile stations are used in the same spectrum, a capacity gain can be realized such that, for example, either more AMR mobile stations can be allowed into the system or more EFR mobile stations can be allowed into the system.

[0047] A similar strategy is applied for the uplink direction, where a base station commands the mobile stations to set the power for uplink transmissions. Consequently, a base station can control uplink transmissions at least partially based on the voice codec type used in a connection when transmitting speech. Mobile stations communicating speech with an AMR codec are thus instructed to use an output power that is substantially lower than that used by mobile stations communicating speech with a voice codec that is less robust than the AMR codec.

[0048] In GSM, a handover is performed when a mobile station moves between two cells. The handover protocol transmits handover control signaling

information using the FACCH (Fast Associated Control Channel). Currently, the FACCH is designed for operation with the EFR voice codec. Consequently, handover signaling may degrade when operated with an AMR voice codec, since an AMR voice codec is more robust and is less susceptible to interference.

[0049] To address this situation, according to an exemplary embodiment of the present invention, in step 310 of FIG. 3A, the transmission powers for communicating associated control signaling information with the second type of mobile station are set to substantially the same transmission powers used for communicating associated control signaling information with the first type of mobile station. For example, the transmission power of associated control signaling information for connections using the AMR voice codec can be set to the same power control target as that used for connections where the EFR voice codec is used. The transmission powers for communicating associated control signaling information with the second type of mobile station (e.g., AMR mobile stations) correspond to the maximum allowed power of the first type of mobile station (e.g., EFR mobile stations).

[0050] When communicating associated control signaling information to a mobile station with AMR capability, a base station increases the output power to the output power that would be used for communicating associated control information to a mobile station with a less robust codec than the AMR codec.

During a connection utilizing an AMR codec, when communicating associated control signaling information to a base station, a mobile station with AMR capability increases the output power to the output power that would be used for communicating associated control signaling information from a mobile station with a less robust codec than the AMR codec. This provides for the transmission of associated control signaling information with the same quality and performance as the associated control signaling information transmitted for mobiles using less robust voice codecs than the AMR codec.

[0051] According to this embodiment, there will be substantially no quality decrease of the control signaling information for the AMR mobile stations and, for example, important control signaling information, e.g., handover signaling information, can be carried with the same quality as if the system were serving only EFR mobile stations. Associated control channels that can be power controlled in the same way irrespective of voice codec used include the FACCH and the Slow Associated Control Channel (SACCH). The same principles can be used with other associated control channels.

[0052] FIG. 3B illustrates an alternate exemplary embodiment of the present invention for controlling the transmission powers for communicating control signaling information. Steps 300 and 305 are the same as those illustrated in FIG. 3A. However, in step 315 of FIG. 3B, transmission powers for communicating

associated control signaling information with the second type of mobile station on downlink connections are set to substantially the same transmission powers used for communicating associated control signaling information with the first type of mobile station on downlink connections. In step 320, transmission powers for communicating associated control signaling information with the first and second types of mobile stations on uplink connections are set according to at least a type of speech unit used by the first and second types of mobile stations, respectively. Thus, when communicating associated control signaling information to a mobile station with AMR capability, a base station increases the output power to the output power that would be used for communicating associated control information to a mobile station with a less robust codec than the AMR codec.

[0053] According to this alternate embodiment, the downlink transmissions of associated control signaling information are transmitted with a power that corresponds to the power used for transmitting associated control information in the downlink on a connection utilizing an EFR codec. The uplink transmissions of associated control signaling information can instead rely on advanced receiver algorithms and methods, since it is much easier to implement these type of features in the base station than in the mobile stations. For example, in mobile stations using the AMR voice codec for speech transmissions, the EFR power control target can be used in the downlink connection for associated control

signaling information, while, for example, Interference Rejection Combining (IRC) can be used to improve the performance of the uplink connection for transmitting associated control signaling information. Other types of receiver techniques that improve uplink performance can also be used.

[0054] FIG. 5 illustrates a system for controlling transmission powers in a cellular communication system in accordance with an exemplary embodiment of the present invention. FIG. 5 shows a cell 500, where a base station 510 serves MOBILE_1 505 with a voice communication call utilizing the AMR voice codec, and additionally serves MOBILE_2 515 with voice communication call utilizing a GSM EFR voice codec. The quality target (in terms of perceived speech quality) for MOBILE_1 505 is the same as for MOBILE_2 515.

[0055] The system for controlling transmission powers can include a first type of mobile station (e.g., MOBILE_1 505), wherein the first type of mobile station includes a first type of speech unit, and wherein a first connection with the first type of mobile station targets a first radio channel quality. The system includes a second type of mobile station (e.g., MOBILE_2 515), wherein the second type of mobile station includes a second type of speech unit, and wherein a second connection with the second type of mobile station targets a second radio channel quality. The first type of speech unit of the first type of mobile station is less robust to poor radio channel quality than the second type of speech unit of the

second type of mobile station. The transmission powers for the first and second connections are set according to at least a type of speech unit used by the first and second types of mobile stations, respectively, when transmitting speech. According to exemplary embodiments of the present invention, the first type of speech unit used by the first type of mobile station is an EFR voice codec unit, and the second type of speech unit used by the second type of mobile station is an AMR voice codec unit. The system also includes a base station (e.g., base station 510) that communicates with the first and second types of mobile stations.

[0056] According to exemplary embodiments, the first and second types of mobile stations share substantially the same frequency band for the first and second connections. In addition, frequency hopping allocations can be used for the first and second connections. According to exemplary embodiments, $MOBILE_2$ 515 (i.e., the AMR mobile station) can have a power control target for its connection in both uplink and downlink directions that is substantially lower than the power control target for the connection to $MOBILE_1$ 505 (i.e., the EFR mobile station) in both uplink and downlink directions.

[0057] The first and second radio channel qualities and power control target can correspond to, for example, a desired carrier-to-interference (C/I) ratio or any other form of radio channel quality measure. According to exemplary embodiments, the second radio channel quality is substantially lower than the first

radio channel quality. In such an embodiment, two different radio quality targets are used for the power control feature of the present invention — a high radio channel quality target for mobile stations equipped with the EFR voice codec (i.e., the first type of mobile stations) and a lower radio channel quality target for mobile stations equipped with the AMR voice codec (i.e., the second type of mobile stations).

[0058] According to an alternate exemplary embodiment, the radio channel quality used for EFR mobile stations can be used for both EFR and AMR mobile stations. In such an alternate embodiment, two different radio channel quality mappings are needed, for example, bit error rate to speech quality, or any other form of radio channel quality measure. The second radio channel quality is mapped from a corresponding first radio channel quality. The user-perceived quality of the second radio channel quality for the second type of mobile station corresponds to substantially the same user-perceived quality of the first radio channel quality for the first type of mobile station. According to exemplary embodiments, the minimum power used for the second connection with the second type of mobile station (the AMR mobile station) is lower than the minimum power used for the first connection with the first type of mobile station (the EFR mobile station).

[0059] According to an exemplary embodiment of the present invention, the transmission powers for communicating associated control signaling information with the second type of mobile station are set to substantially the same transmission powers used for communicating associated control signaling information with the first type of mobile station. Thus, the transmission power of associated control signaling information for connections using the AMR voice codec is set to the same power control target as that used for connections where the EFR voice codec is used. The transmission powers for communicating associated control signaling information with the second type of mobile station correspond to the maximum allowed power of the first type of mobile station.

[0060] According to an alternate exemplary embodiment of the present invention, transmission powers for communicating associated control signaling information with the second type of mobile station on downlink connections are set to substantially the same transmission powers used for communicating associated control signaling information with the first type of mobile station on downlink connections. The transmission powers for communicating associated control signaling information with the first and second types of mobile stations on uplink connections are set according to at least a type of speech unit used by the first and second types of mobile stations, respectively.

[0061] Thus, according to exemplary embodiments of the present invention, a power control unit controls the power of connections differently where the AMR voice codec is used than for connections where the GSM EFR voice codec is used. FIG. 6 illustrates a power control device according to an exemplary embodiment of the present invention. In FIG. 6, a Power Control Unit 600 has as an input parameter at least the type of voice codec used in a target communication. Although the illustration in FIG. 6 indicates a power control unit 600 divided into one power control part for an AMR power control 602 and one power control part for an EFR power control 604, the same power control part can handle both types of regulation through, for example, a power control feature that uses at least the voice codec type as an input parameter.

[0062] FIG. 7 illustrates the target radio qualities for the different types of transmissions according to exemplary embodiments of the present invention. As shown in FIG. 7, the target radio qualities for the AMR voice codec associated control signaling quality 710, EFR voice codec quality 715, and EFR voice codec associated control signaling quality 720 are substantially equivalent, and each greater than the target radio quality for a AMR voice codec quality 705.

[0063] FIG. 8 illustrates a simulated histogram of power levels for EFR mobile stations and for AMR mobile stations — EFR mobile station power level 810 and AMR mobile station power level 805, respectively. The AMR and EFR

connections both aim towards the same perceived quality measure. It can be seen from FIG. 8 that there is a significant difference in output power (horizontal-axis) between the EFR and the AMR connections. It is this difference that can be translated into a capacity increase using exemplary embodiments of the present invention. In particular, for handling associated control signaling information, the performance of the associated control channels will remain at the performance level of a system in which only EFR mobile stations are served.

[0064] Although the present invention has been described with reference to a GSM cellular communication system and, in particular, to an AMR voice codec, those of ordinary skill in the art will recognize that exemplary embodiments of the present invention can provide the same advantages in other types of communication systems, and is equally applicable to other types of codecs and features that improve communication link robustness.

[0065] It will be appreciated by those of ordinary skill in the art that the present invention can be embodied in various specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are considered in all respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims, rather than the foregoing description, and all changes that come within the meaning and range of equivalence thereof are intended to be embraced.